Canadian Centre for Occupational Health and Safety

Centre canadien d'hygiène et de sécurité au travail

A BASIC GUIDE TO INDUSTRIAL VENTILATION

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Canadian Centre for Occupational Health and Safety

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CCOHS/CCHST

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TABLE OF CONTENTS

	PREFACE	(ii)
1.	INTRODUCTION	1
	Purposes of Ventilation	1
	Types of Ventilation	1
2.	GENERAL OR DILUTION VENTILATION	1
3.	LOCAL EXHAUST VENTILATION	3
	Hoods	6
	Ducts	10
	Air Cleaning Devices	10
	Types of Air Cleaning Devices for Dusts and Other Particulates	12
	Types of Air Cleaning Devices for Gases and Vapours	13
	Fans	13
	Make-Up Air	15
4.	CHECKING THE EFFECTIVENESS OF A LOCAL EXHAUST VENTILATION SYSTEM	15
	REFERENCES	18
	FURTHER READING	19

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PREFACE

Ventilation is a major way of effectively controlling exposure to airborne contaminants in industry. Ventilation is also required or recommended in many occupational health and safety regulations.

This publication is intended to be a practical source of information for anyone who needs to know about some of the basic principles of industrial ventilation, how its effectiveness can be checked, and where to go for more help.

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1. INTRODUCTION

Ventilation supplies and moves air through spaces. It also removes air which contains airborne contaminants from spaces thereby reducing the concentration of contaminants in the workplace, and reducing worker exposure.

Purposes Of Ventilation

There are four purposes of ventilation:

- Provide a continuous supply of fresh air containing oxygen.
- Maintain temperature and humidity at comfortable levels.
- Reduce potential fire or explosion hazards.
- Remove or dilute airborne toxic substances.

Types Of Ventilation

- General or dilution ventilation reduces the concentration of the contaminant by mixing and diluting the contaminated air with clean, uncontaminated air.

- Local exhaust ventilation captures contaminants at or near the point where they are generated and removes them.

Table 1 compares the advantages and disadvantages of general or dilution ventilation and local exhaust ventilation.

2. GENERAL OR DILUTION VENTILATION

General ventilation, or as it is sometimes called, dilution ventilation, supplies or exhausts large amounts of air into, or from, an area or building. This is usually done by large wall or ceiling intake or exhaust fans. Sometimes, general ventilation is provided by opening doors and windows. But this is not a reliable way of providing the amount of air that may be necessary. A mechanical ventilation system which uses fans to move the air is much better.

General ventilation can effectively remove large amounts of hot or humid air, or dilute low concentrations of low toxicity contaminants. General ventilation does not eliminate the exposure to an airborne contaminant. It only reduces the concentration by mixing the contaminated air with clean, uncontaminated air. General or dilution ventilation is limited in its ability to control airborne contaminants. It should not be used for fumes and dusts because they are usually too heavy, too toxic, and can be produced too suddenly in large amounts.

Table 1 - Comparison of general or dilution and local exhaust ventilation

General or Dilution Ventilation		Local Exhaust Ventilation	
Advantages	Disadvantages	Advantages	Disadvantages
1. Generally lower equipment & installation costs than for local exhaust ventilation.	1. Does not eliminate workers' exposure to contaminated air.	1. Captures contaminants at source and removes them from the workplace.	1. System design and installation can be expensive for certain applications.
2. Effective control for amounts of low and medium toxicity solvents.	2. Not appropriate for high toxicity vapours and gases.	2. Can handle all types of contaminants, including particles such as dusts and metal fumes.	2. Requires regular cleaning, inspection and maintenance.
3. Effective control for flammable or combustible gases and vapours.	3. Not appropriate for large amounts of any gases and vapours.	3. Requires small amounts of make-up air since local exhaust ventilation uses lower exhaust volumes than general ventilation.	
4. Requires less maintenance than local exhaust ventilation.	4. Ineffective for particles such as dusts or metal fumes.	4. Low ongoing energy costs because of low amounts of make-up air.	
	5. Requires large volumes of heated or cooled make-up air.	5. Only choice for highly toxic airborne materials.	
	6. Not effective for handling surges of gases or vapours or irregular emissions.		

Adapted from: Ventilation: A Practical Guide, 1984, Table 4, p. 25.

General ventilation can be used to dilute vapours, mists or gases if:

- the amount of vapour, mist or gas produced is small, so that it can be diluted to a safe concentration without the need for large amounts of fresh air;
- workers are far enough from the source of the vapour, mist or gas that the exposure levels are below recommended limits;
- the vapour, mist or gas is only slightly or moderately toxic; and
- the vapour, mist or gas is produced at a constant rate, so its concentration in the air is fairly constant and predictable.

Because general ventilation moves large amounts of air over a wide area, it is difficult to control the air flow, especially in workplaces where partitions, machines and other obstacles may block or change the direction of the air flow. It can be effective if air inlets and exhaust fans are located in such a way that the air is drawn away from the workers' breathing zone. Figure 1A illustrates examples of poor air inlet and fan locations and Figure 1B illustrates examples of better air inlet and fan locations.

The air inlet and fan locations shown in Figure 1A should be avoided because the air flow draws the contaminants into the breathing zone of the worker. The arrangements of air inlets and fans as shown in Figure 1B are better because they create an air flow which draws the gas, vapour or mist away from the worker's breathing zone. Make-up air, the air introduced to replace the exhausted air, should be heated in winter and cooled in the summer as needed.

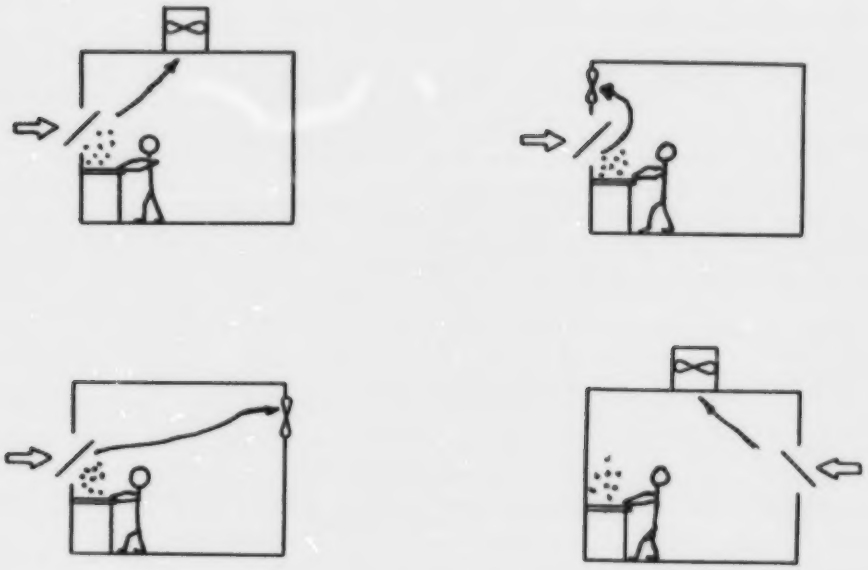
2. LOCAL EXHAUST VENTILATION

Local exhaust ventilation systems are designed to remove airborne contaminants from as close as possible to their source. They operate on the principle that air moves from an area of high pressure to an area of low pressure if the difference in pressure is maintained. The difference in pressure is created by a fan that draws air through the ventilation system. In principle, the operation of a local exhaust ventilation system resembles that of a household vacuum cleaner.

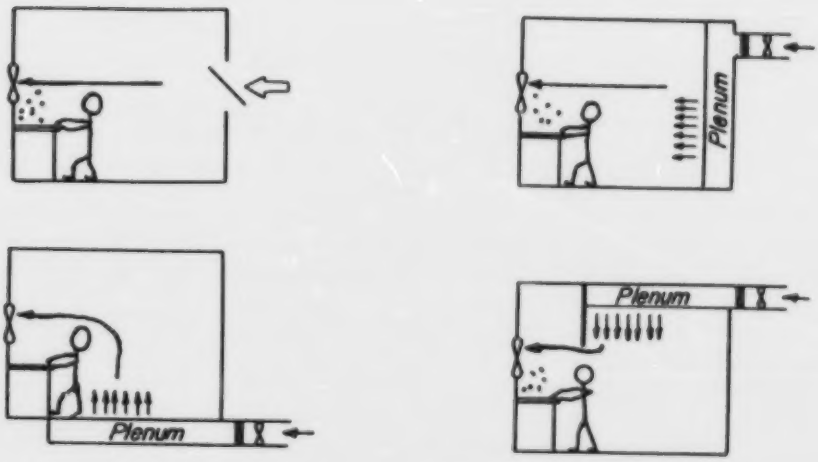
A local exhaust ventilation system has these basic elements:

- Hoods that capture the contaminants at the source.
- Ducts that transport the airborne contaminants.
- Air cleaning devices that remove the contaminants from the air.
- Fans that move the air through the ventilation system and discharge the exhausted air outside.
- Make-up air that replaces the exhausted air.

Figure 2 illustrates the basic parts of a local exhaust ventilation system.



A. Examples of Poor Air Inlet and Fan Location



B. Examples of Better Air Inlet and Fan Location

Figure 1 - Principles of general or dilution ventilation

Adapted from: Industrial Ventilation, 1986, figure 2-1, p. 2-3

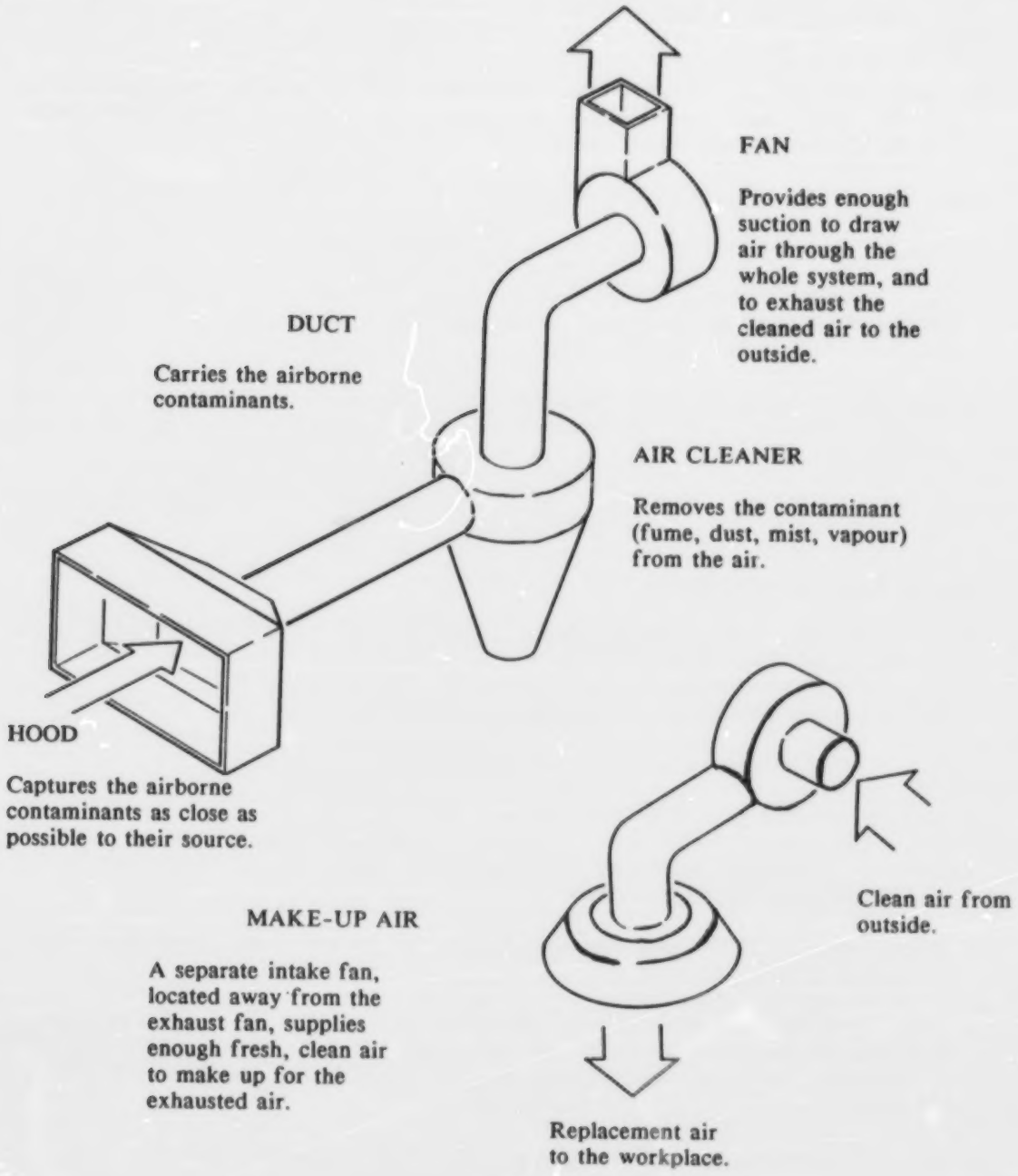

FAN
Provides enough suction to draw air through the whole system, and to exhaust the cleaned air to the outside.
DUCT
Carries the airborne contaminants.
AIR CLEANER
Removes the contaminant (fume, dust, mist, vapour) from the air.
HOOD
Captures the airborne contaminants as close as possible to their source.
MAKE-UP AIR
A separate intake fan, located away from the exhaust fan, supplies enough fresh, clean air to make up for the exhausted air.
Clean air from outside.
Replacement air to the workplace.

Figure 2 - Parts of a local exhaust ventilation system

Hoods

A hood confines or captures the contaminant at its source. The three major types of hoods used in industry are enclosures, receiving hoods and capturing hoods. These are illustrated in Figure 3.

The choice of hood depends on several factors.

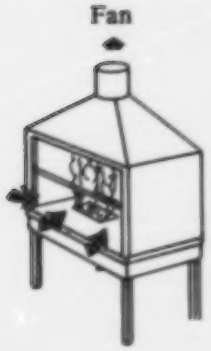
- Whether the contaminant is a dust, fume, mist, vapour or gas.
- The toxicity of the contaminant. Local exhaust ventilation should be used to control exposure to substances that are considered to be highly toxic.
- How the contaminant is produced. Local exhaust ventilation can be used if the contaminant is localized, such as fumes from welding, or if the contaminant is released in surges such as dust from a grinding wheel.
- Work requirements. The size, shape and location of the hood should not interfere with the work process.

General Rules For Hood Design

Each hood type has specific design requirements, but several general principles apply to all hoods.

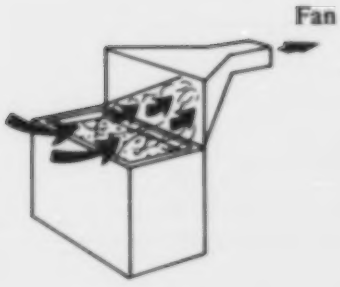
- Enclose the source of the contaminant as much as possible.
- Place the hood as close as possible to the source.
- Provide enough air flow to capture and remove the contaminant at the source before it reaches the worker's breathing zone. Recommended air flows or "capture velocities" for different types of contaminants can be found in reference books on ventilation.
- Direct the air flow so the contaminant is drawn away from the worker and toward the hood opening.
- Take advantage of the natural movement of contaminants. For example, a hood should be placed above hot processes to trap rising gases and heat. A grinding wheel or woodworking machine should be equipped with a partial enclosure to trap the particles as they spin off.
- Use of flanges or baffles around the hood opening increases the capture effectiveness and reduces ventilation air requirements.

Some of these principles are illustrated in Figures 4 and 5.



a) Enclosures - contain contaminants released inside the hood

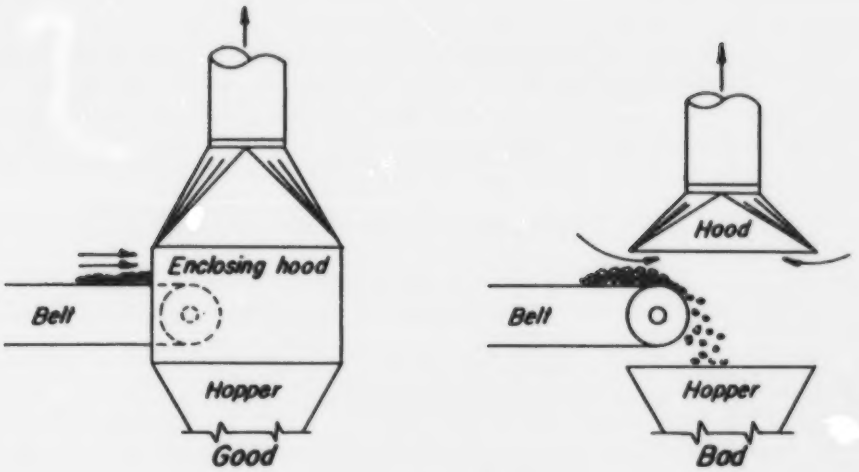
b) Receiving hoods - catch contaminants that rise or are thrown into them



c) Capturing hoods - reach out to draw in contaminants

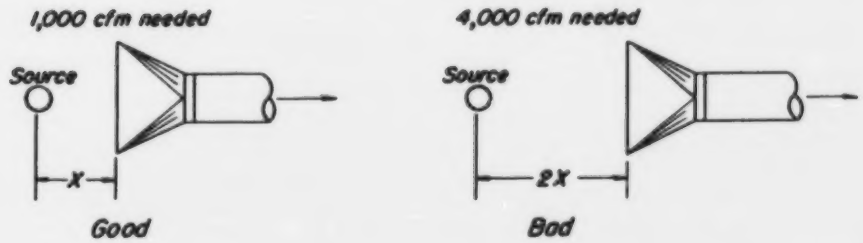
Figure 3 - Three major types of hoods

Adapted from: Handbook of Ventilation for Contaminant Control, 1976, figure 5-7, p. 107



ENCLOSE

Enclose the operation as much as possible. The more completely enclosed the source, the less air required for control.

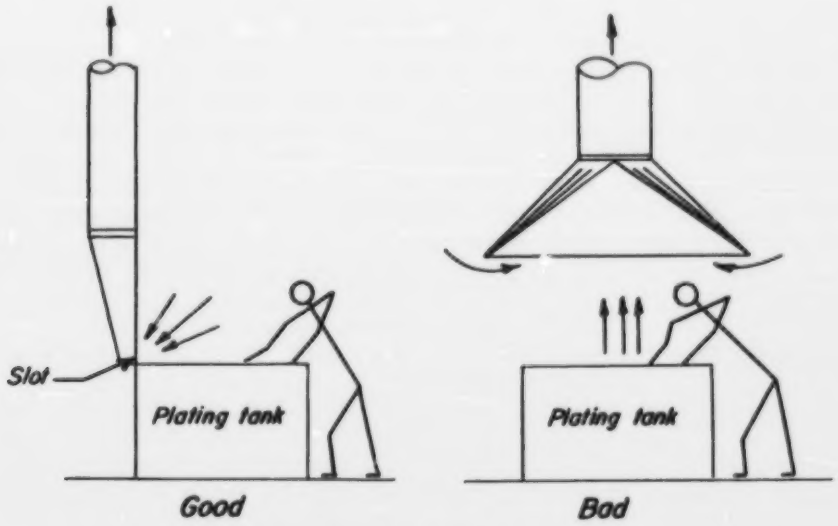


LOCATION

Place hood as close to the source of contaminant as possible. The required volume varies with the square of the distance from the source.

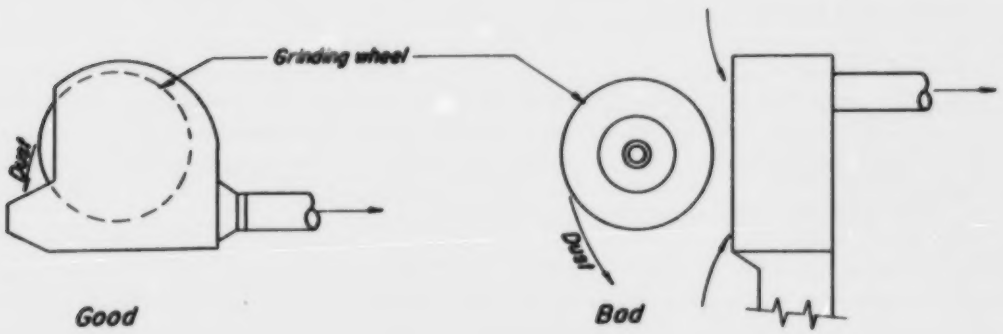
Figure 4 - Exhaust hood design principles

Adapted from: Industrial Ventilation, 1986, figures 4-9 and 4-10, p. 4-13, 4-14



DIRECTION OF AIR FLOW

Locate the hood so the contaminant is removed away from the breathing zone of the worker.



LOCATION

Locate and shape the hood so the original velocity of the contaminant will throw it into the hood opening.

Figure 5 - Exhaust hood design principles

Adapted from: Industrial Ventilation, 1986, figures 4-10 and 4-11, p. 4-14, 4-15

Ducts

A duct carries the airborne contaminants from the hood to the air cleaning device. To do this effectively, the air must flow through the ducts with as little friction or resistance as possible. Any resistance slows down the air travelling through the ducts and reduces the capture velocity at the hood. If the air in the duct is not travelling fast enough, solid contaminants such as dusts and fumes will settle out and may eventually clog the duct. On the other hand, excessively high velocities are wasteful of power and may cause rapid abrasion of the duct work and noise problems. The speed with which the air moves through the duct is called "duct velocity."

General Rules For Duct Design

- Use only round duct work so that air flows as smoothly as possible. Particles get trapped in corners of square ducts.
- Keep length of ducts as short as possible.
- Use correct duct velocities to keep the particles suspended as the air travels through the duct. Recommended duct velocities for different types of contaminants can be found in reference books on ventilation.
- Keep the number of turns and size changes in a duct system to a minimum.
- Avoid any sharp bends in the duct work. The elbows joining one duct to another should curve gradually (radius to diameter ratio of at least 2) to maintain a smooth air flow.
- Balance systems that have multiple hoods to ensure correct air flow through each hood or duct. There are two ways of balancing a ventilation system that has more than one hood. One way is to use correct duct lengths and diameters when designing the system. The second way is to install balancing dampers or blast gates in the ducts which can be adjusted after the ventilation system is installed.
- Duct work should extend at least two duct diameters away from the fan inlet to maintain a smooth air flow at the suction side of the fan.

Air flow through ducts can also be improved by eliminating any leaks or holes in the duct and by inspecting and cleaning ducts regularly. Figure 6 illustrates some basic duct design principles.

Air Cleaning Devices

Air cleaning devices capture and remove airborne contaminants from the air that has been drawn from the workplace.

The choice of air cleaning devices depends on several factors.

- Whether the contaminant is a dust, fume, mist, gas or vapour.
- Concentration of the contaminant.

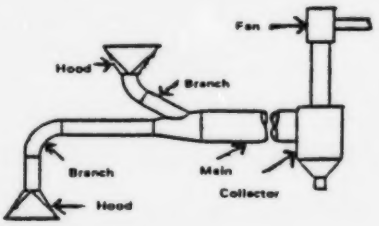
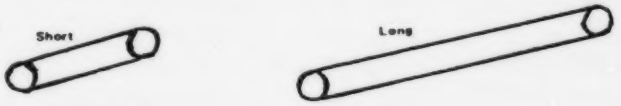
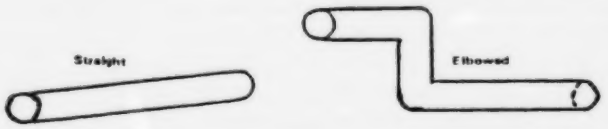
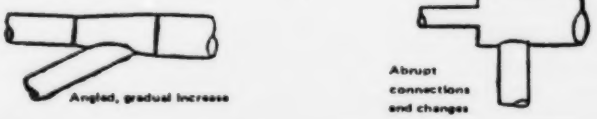
Principle	Good	Bad
Streamline the flow of the entire system. Avoid anything which creates turbulence and resistance.		
Short runs offer less resistance than long runs.		
Straight runs offer less resistance than runs with elbows and bends.		
Branches should enter joints at right angle. Expansions in duct size to handle increased air volume should be gradual.		
Elbows with a wide radius offer less resistance than a short radius elbow.		
Larger diameter ducts offer less resistance than smaller ones.		

Figure 6 - Duct design principles

- Particle size of solid contaminants such as dusts or fumes.
- Amount of contaminant that must be removed from the exhaust air to meet environmental standards.
- Temperature and moisture content of exhausted air.
- The properties of the contaminant. Is it corrosive, such as acids; abrasive, such as sand; or sticky, such as metallic buffing dust?
- Available workspace and collector size. Collectors vary considerably in size and shape.
- Disposal methods for the collected material.
- The amount of noise generated by the air cleaning device.

Types of Air Cleaning Devices for Dusts and Other Particulates

Dust collectors are the most widely used air cleaning devices in industry, since dusts are the most common form of airborne contaminants. Dust collectors include cyclone collectors, fabric collectors and electrostatic precipitators.

Cyclone Collectors

Cyclones, also called centrifugal collectors, remove coarse to medium-sized particles by spinning the particle-laden air in a cone-shaped chamber. The particles are thrown to the edge of the spinning airstream, then settle out. This method is not effective for removing very fine particles.

Cyclones are particularly useful in woodworking operations in which large-to-medium size dust particles are found. Cyclones are very durable and require little maintenance.

Fabric Collectors

Fabric collectors, also called "bag houses," remove medium to very fine dust particles. They trap dusts by slowly passing air through layers of fabric. Gradually, a dust layer accumulates on the fabric. This dust also acts as the filter initially improving the dust collecting effectiveness of the system. After continued use, the fabric becomes clogged. The dust must be removed by either an automatic system which shakes the dust from the fabric or by changing the fabric bags. Fabric collectors are widely used in dusty operations such as foundries.

Electrostatic Precipitators

Electrostatic precipitators remove fine particles from the air by placing an electrical charge on the particles. These particles are then attracted to an oppositely charged collection plate. Electrostatic precipitators are very efficient for collecting fine particles but cannot be used in very dusty operations because they clog easily.

Electrostatic precipitators should not be used around flammable chemicals because an explosion could result if a spark is given off in the collector. They can effectively remove fumes and fine particles but not gases or vapours from the air.

Types of Air Cleaning Devices for Gases and Vapours

Gases and vapours are more difficult to separate from the exhaust air than are dust particles.

Several types of air cleaning devices can be used for collecting gases and vapours. They include wet collectors, scrubbers and charcoal filters that trap vapours and gases, and combustion incinerators that burn off any combustible gases before they are released into the atmosphere.

Fans

Fans are the driving force of the entire local exhaust ventilation system. They must provide enough air pressure difference to capture contaminants at the source, draw them into the hood, carry them through the duct work and the air cleaning device, and exhaust the cleaned air into the outside air.

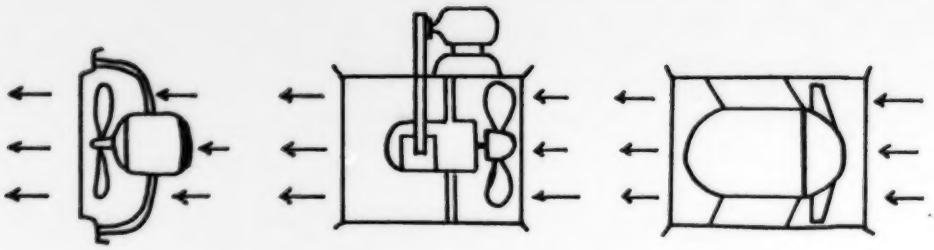
Two major types of fans are used for industrial ventilation--axial flow fans which draw air straight through the fan and centrifugal fans which pull air into the centre of the fan and exhaust it at right angles to the fan's blades. Examples of these types of fans are shown in Figure 7.

The choice of fan depends on several factors.

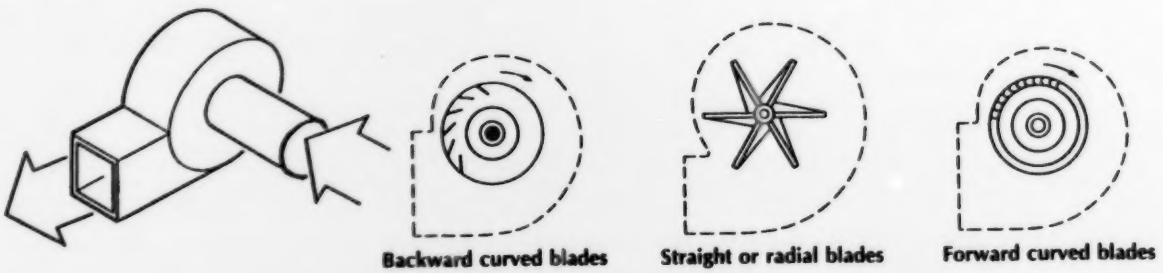
- Whether the contaminant is a dust, fume, mist, gas or vapour.
- How much air has to be moved through the local exhaust system.
- The amount of resistance in the exhaust system that the fan has to overcome (fan static pressure).
- The amount of energy needed to move the air (fan efficiency).
- Flammability of the contaminants: non-sparking construction or explosion proof motors may be needed.
- Corrosiveness of the contaminants; non-corrosive materials may have to be used in construction of the fan and motor.
- The amount of adjustment required: fan speed can be adjusted on a limited basis on belt-driven fans, but there is usually only one fixed speed for direct-drive fans.
- Space limitations for the location of the fan.
- The amount of noise or heat generated by the fan.

Axial Flow Fans

The most commonly used axial flow fan is the propeller fan which is similar to the common household fan. Propeller fans may be acceptable for cooling and in some cases for general or dilution ventilation. They can move large amounts of air against low air pressure with a minimum amount of electrical energy. However, these fans cannot be used in local exhaust ventilation systems because they do not provide enough suction to draw air through a hood and duct system.



Axial Flow Fans
Air leaves in the same straight line in which it enters.



Centrifugal Fans
Air leaves at right angles to the direction in which it enters.
The straight or radial blade fan is most common.

Figure 7 - Basic types of fans used for ventilation

Adapted from: Ventilation: A Practical Guide, 1984, figure 13, p. 51

Centrifugal Fans

Centrifugal fans generate much more suction than propeller fans. The most commonly used centrifugal fan in industrial ventilation is the radial or straight blade fan. It is used because it can effectively exhaust solid particles such as dusts without clogging the blades.

Table 2 compares the advantages and disadvantages of centrifugal and propellor fans for various contaminants.

Fan Discharge

Air discharged from a fan should be kept away from inlets of the make-up air system. In this way the make-up air system will draw only clean, outdoor air into the workplace. Also, the discharge exhaust stack should be high enough from the roof so that contaminants do not re-enter the workplace.

Make-up Air

An important and sometimes overlooked aspect of local ventilation is the need to provide enough air to replace the air that is exhausted from the workplace. If enough make-up air is not provided when large volumes of air are exhausted, the workplace becomes "starved" for air and negative pressure is created. Negative pressure in the workplace increases resistance on the ventilation system causing it to move less air.

A separate intake fan, located away from the exhaust fans, should be used to bring in fresh, uncontaminated air from outside. This air must be clean and heated in winter or cooled in summer, as needed.

4. CHECKING THE EFFECTIVENESS OF A LOCAL EXHAUST VENTILATION SYSTEM

There are two ways of checking whether a local exhaust ventilation system is working properly. The first is to take measurements of the air flow at different points in the system to make sure that the air velocities or volumes for which the system was designed are actually achieved. Air flow measurements should be made at specific points in the ventilation system, such as at the hood, in the ducts, at the air cleaning device and at the fan. The results should then be compared to the values calculated in the original design drawings or blueprints.

The second way of checking a ventilation system is to measure the concentration of contaminants in the air while the ventilation system is on. If it is working properly, exposure levels should be below recommended limits.

Table 2 - Fan selection

	Propeller fan (axial)	Forward curved fan (centrifugal)	Backwardly inclined fan (centrifugal)	Airfoil fan (modification of backwardly inclined fan)	Radial fan (centrifugal) (straight blades)
Dilution Ventilation	YES	YES	NO**	NO**	NO**
Local Exhaust Ventilation	NO*	YES	YES	YES	YES
"Clean Air"	YES	YES	YES	YES	YES
Vapours, Solvents, and Gases	YES	YES	YES	YES	YES**
Dust and Other Particles	NO	NO	FINE DUST AND FUME	NO	YES HEAVY DUSTS
System Resistance (Static Pressure)	LOW	LOW TO HIGH	LOW TO HIGH	LOW TO HIGH	LOW TO HIGH
Advantages	Good for cooling and dilution ventilation. Moves large volume of air against low resistance.	Good for dilution and "clean air." Inexpensive. Widely available. Low noise.	Non-overloading characteristic makes this safest fan selection for varying resistance systems.	Most efficient for very clean air.	Most suitable fan for exhausting dust.
Disadvantages	Not good for local exhaust ventilation. Exhaust volume quickly decreases as resistance increases.	Not to be used for dust. Easily clogged by dust and sticky vapours.	Not used for heavy dust.	Should not be used for dirty air.	Overall efficiency is lowest of all fan types.

* Sometimes used in direct venting spray booths.
** Not efficient but could work.

Adapted from: Ventilation: A Practical Guide, 1984, table 10, p. 53

Both types of measurement should be carried out by trained people such as occupational hygienists or ventilation specialists using specialized equipment. But some observations can be made and some simple tests can be done by anyone to estimate whether a ventilation system is working properly.

Here are some questions to consider.

- Can you see any dusts, fumes or mists in the air or covering nearby surfaces?
- Can you smell any gases or vapours?
- Do any workers feel eye, nose or throat irritation or any other symptoms that may be caused by a chemical exposure?

If the answer is "YES" to any of these questions, the ventilation system may not be adequate.

Many dusts, fumes, gases and vapours are odourless, non-irritating and invisible, so not seeing or smelling chemical contaminants does not necessarily mean that the ventilation system is working properly. That is why air sampling for specific contaminants is the best way of finding out if exposures are below recommended levels.

There are some simple ways of checking the air flow into a hood. Smoke tubes that emit a highly visible smoke are made for this purpose. When smoke is released in front of the hood or at the source of the contaminant, the hood should draw it away quickly and completely. If the smoke is not captured completely, then the hood may not be working properly.

Smoke tubes are inexpensive and can be bought from safety equipment suppliers.

If any of the tests suggest that a ventilation system is not working properly, the following could be checked.

- The fan belt is worn or slipping, the fan is wired incorrectly, or if the fan is rotating in the wrong direction.
- The air cleaner is clogged or needs replacement.
- There is an obstruction in the duct work caused by a closed damper or an accumulation of material.
- Inadequate make-up air is being supplied.

If the problem cannot be found, a ventilation specialist should be consulted.

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